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The electrical and structural properties of granular superconducting Sn on InSb(1 1 0)

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Abstract

This study shows an influence of morphology on the superconducting properties of thin granular Sn films (40–100 nm) measured in a wide temperature range (2–300 K) and up to 8 T extended magnetic field. The films were evaporated under UHV conditions onto a cleaved InSb(1 1 0) surface at room temperature. We have investigated the morphology of the Sn films with several methods (LEED, AES, AFM, Raman) and used DC-conductivity, AC- and DC-susceptibility measurements to determine the critical temperature and the upper critical field. We observe a decrease of the superconducting critical temperature and an angular dependence of the upper critical field.

Keywords: Superconducting critical temperature; Sn/InSb; Upper critical field

1. Introduction

The superconducting properties of thin films are dependent on many parameters like film thickness, temperature treatment, impurities, etc. In an early work Buckel and Hilsch [1] found e.g. for quench condensed films of Sn and other metals a dependence of the critical temperature T_c from substrate temperature. Newer investigations concentrated on the insulator–superconductor transition in granular quench condensed films of a few nm thickness [2,3]. We report here on the superconducting and structural properties of β-Sn domains incorporated in an α-Sn thin film.

2. Results and discussion

2.1. Experimental details

The Sn films were evaporated under UHV conditions onto a cleaved InSb(1 1 0) surface at room temperature. The film thickness t varies between 40 and 100 nm (250–650 ML). The samples were characterized in situ with LEED and AES and ex situ with AFM, X-ray scattering and Raman spectroscopy. After the structural characterization DC-conductivity and AC- and DC-susceptibility measurements were made in ^{4}He-cryostats. The films have a special geometry (microbridge 1.5 mm × 150 μm) so that we could use the four-point-method for resistance measurements.

2.2. Structure and morphology

The LEED pattern of the (1 × 1) substrate reconstruction vanishes after deposition of more than 2 ML. For higher coverage there is only an increasing background signal visible. With AES we notice a change from the earlier observed layer by layer growth [5] towards an island growth at a coverage around 10–15 ML. The LO Raman mode of the semiconducting α-Sn occurs in all grown samples, confirming the stabilization of α-Sn by the substrate as seen in Ref. [4]. Additionally, the TO mode of the metallic β-Sn can be seen in samples thicker than 64 nm (not shown here). Typical AFM images are shown in Fig. 1. They show discontinuous films and an

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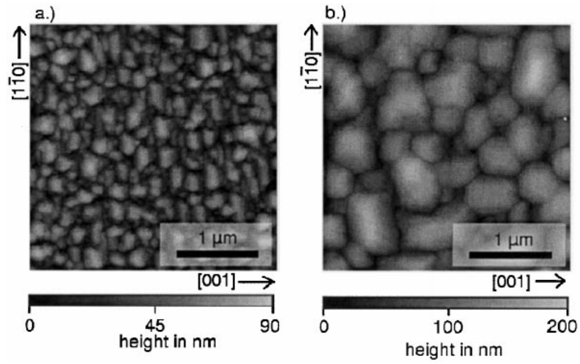

Fig. 1. AFM images of Sn/InSb with: (a) $t \approx 40$ nm and (b) $t \approx 100$ nm.

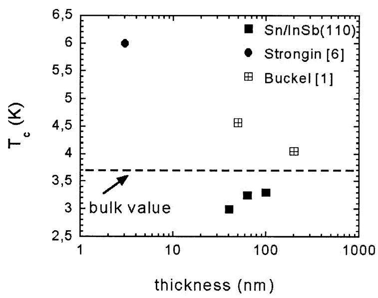

Fig. 2. T_c versus film thickness of Sn/InSb(1 1 0).

increasing size of the islands with film coverage. The islands are oriented along crystal axes of the substrate.

2.3. Superconductivity

Superconductivity was observed for all investigated samples. The superconductivity was recognized by a sharp drop of the resistance and by the onset of the decrease in the magnetic susceptibility. In contrast to investigations for quench condensed films [1,6] the T_c value is always lower than the bulk value (3.7 K) and decreases with decreasing film thickness (Fig. 2). In resistance measurements at high pressure on Sn [7] T_c values lower than 3.7 K were found. In addition, the critical magnetic field H_c is higher than the field for quench condensed films in a similar thickness region and it has an angular dependence. This angular dependence of H_c is similar to a type-I-to-type-II-superconductor transition and was first described in detail by Tinkham [8].

Epitaxial grown thin α-Sn films on CdTe(0 0 1) are not superconducting for temperatures > 2.1 K [9]. Therefore, we conclude that the origin of the superconducting behavior in our films results from the β-Sn island within the film. Below 64 nm the amount of β-Sn is maybe to small to be detected by Raman spectroscopy.

Acknowledgements

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